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SOME NOTES ON THE LAKES AND VALLEYS OF THE UPPER NUGSUAK PENINSULA, NORTH GREENLAND[1]

INTRODUCTORY STATEMENT

THE Upper Nugsuak peninsula is located in north latitude 74° 5′–15′; is 25 to 30 miles long, averaging from four to six miles in width, and has a due southwest trend with the general coast line of Greenland. This part of the coast is characteristically rough and rugged. The marginal strip—at present ice-free—is intersected by numerous fjords, which, in many cases, penetrate to the very edge of the ice-cap, cutting the uncovered land into numerous islands and peninsulas. A considerable part of the uncovered lands is occupied by lakes.

The peninsula is limited on its north and south sides, by fjords descending to depths of not less than 300 to 500 fathoms, and varies in elevation up to nearly 3000 feet. The hilltops have a general elevation of 1000 to 2000 feet. Its surface is a very rough and irregular one; is cut up by a network of deeply incised valleys, the seaward extension of which add to the ruggedness of the coast line.

The general appearance of the inter-valley areas—hills and ridges—is that of a well rounded moutonnée form, which prevailingly show among the lower hills a highly polished surface, while the higher peaks are as uniformly angular, and are very much less subdued topographic types. Some of the valley slopes are steep, often times precipitous, often with large talus heaps at their bases. The slopes have been trenched and furrowed by running water derived from the melting ice and snows. The scarred and shattered surface everywhere testifies to the great rapidity of frost action. The results of glaciation are conspicuous over all its parts, attesting the fact that the ice-cap has over-ridden its entire surface at some previous time. Remnants of local glaciers still exist among the higher peaks of its northern border. Bowlders are abundant, while the paucity of till is quite marked.

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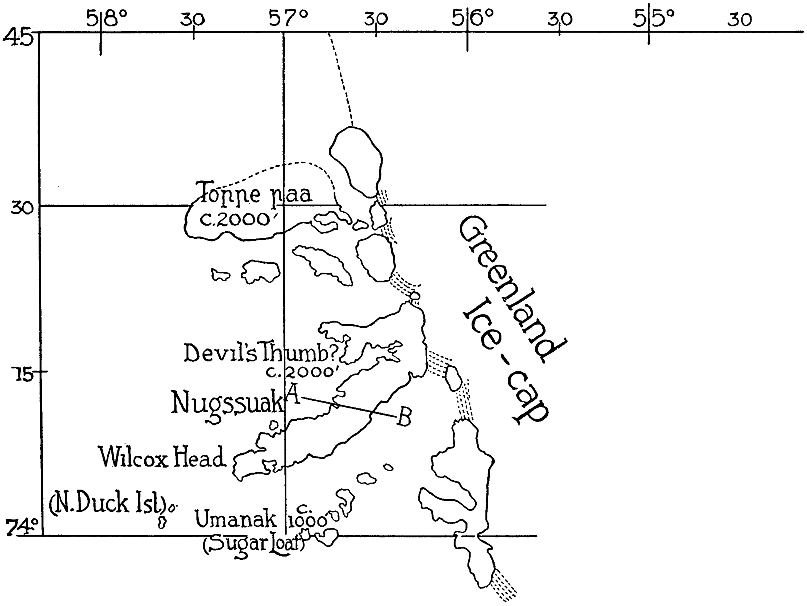
[1] The writer wishes to express his indebtedness to the Cornell University Expedition of 1896, under the directorship of Professor R. S. Tarr, and of which the writer was a member, when this work was made possible. Further acknowledgments are due Professors R. S. Tarr and A. C. Gill, and Messrs. E. M. Kindle, J. O. Martin and J. A. Bonsteel for valuable aid and suggestions — especially Professor Tarr, who kindly read and criticised this paper in manuscript.



Owing to much variation in texture, the intimate relationship of rock structure to topography is well marked, as shown in the case of the dikes of basic rock—diabase (?)—found cutting the gneiss in various directions. The gneiss has been intricately folded and contorted.

LAKE CLASSIFICATION

No large lakes are found on the peninsula. The basins vary in size from one and a half miles in length down to the merest pool. The largest water bodies are confined for the most part to the large valleys; but many tarns are scattered over the higher lands. Both types are, with one or two possible exceptions, true rock-basins, since they are entirely surrounded by rock in place; for there is rarely enough till for a dam. Based primarily on origin, the lakes are grouped under "Rock-basins due to glacial origin," and on position, are further grouped. as (*a*), highland, and (*b*), valley lakes.

ROCK-BASINS OF GLACIAL ORIGIN

The highland lakes.—On account of their salient features, not all the highland lakes can be ascribed as the direct products of glacial erosion; but it is certain that all of them owe their origin, either entirely or in part, to glaciation. Therefore, since this class is in part directly and in part indirectly the products of glaciation, and since no differentiation of those that are ice-scoured basins from those that are perhaps only partially due to glaciation, can be effected, they are both grouped as highland lakes of glacial origin.

This entire group of lakes is composed of small tarns and pools of very shallow depth. Their distribution is apparently controlled entirely by the weaker rock structure. Where the joint planes were numerous and intersected, tiny lakes were often found. Generally, the larger highland basins were found developed in the direction of the strike of the gneiss, and had resulted from the removal of the softer layers of gneiss, by some process of erosion. Still others were observed where these planes of weakness were not apparent, but, in some cases, could probably be ascribed to the result of chemical or mechanical weakness, due to mineral distribution. The lakes are prevailingly irregular in outline, and contain varying amounts of weathered débris scattered over the bottoms of their basins, which is very probably due to recent action.

Their size, distribution, position and intimate relationship to rock structure, and irregularity of outline are sufficient evidence of their having resulted, in part, from differential atmospheric erosion. Scarcely any doubt exists against the large share of these tarns having resulted directly from differential ice scouring along the line of weaker rocks. In other cases, however, the basins have been more or less modified by the ice advance, which served to remove the preglacial decay, resulting in some instances, in a probable deepening from this cause.

Evidence has been brought forward by others, proving that not all trace of minor preglacial form was destroyed by the ice advance over portions of this and the Baffin land coast. Furthermore, that in its advance, all the preglacial decay was not removed, but that a somewhat roughened and irregular surface resulted from such action, mostly along the lines of rock weakness. To the combined action, therefore, of differential preglacial weathering and ice erosion, along the lines of weak structure, are due most, if not all, of the group of highland lakes.

Concerning the origin of this type of lake along the Greenland coast and other similarly glaciated lands in the arctic latitudes Professor Tarr says:[1]

> It is noticeable near Cumberland Sound, as well as in Turnavik, and in Hudson's Strait, and indeed in Greenland, that there are many basins of small size, surrounded entirely by rock. While some of these have no doubt been scoured out by differential ice erosion, the position of many of them along the lines of weaker rocks, indicates that they represent differential preglacial weathering. The advance of the ice in these cases has served to remove the

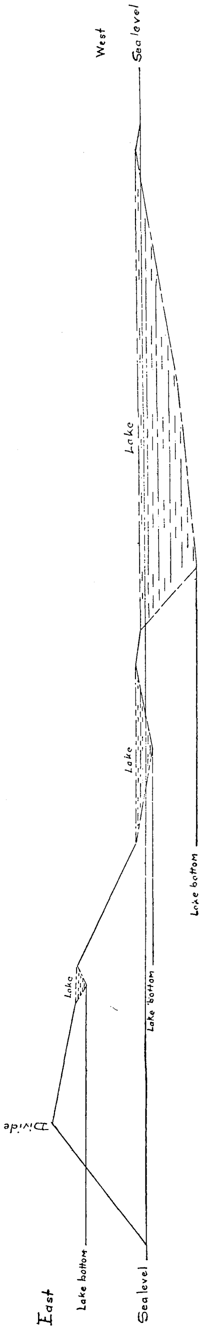


Fig. 1. Profile of valley marked 'AB' Scale $1' = \frac{1}{200}$ inches.

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[1] TARR, R. S.: Amer. Geol. 1897, Vol. XIX, pp. 195, 196.

> decayed rock, and perhaps to deepen the depressions formed by this action, though ice erosion would not in this case be the prime cause for the basin.
>
> These [rock-basins] seem to be depressions caused rather by preglacial decay than by glacial erosion. They are often so small and bounded by walls so angular that origin by ice scouring seems impossible.[1]

The valley lakes.—The line, marked "AB" on the map, indicates the position of one of the largest valleys on the peninsula, with seaward termination on the east and west sides, and is from three and a half to four miles in length. Fig. 3 shows cross-sections, with reference to sea level, of the east and west ends of this valley. "A" was sketched at a point in the valley 165 feet above sea level, while "B" is only 15 feet above. Neither of these has been platted to any scale. A glance at the two is sufficient to note the contrast in outline of the two ends of the valley. The south end, A, is filled in on all sides to an unknown depth with perfectly angular blocks of large dimensions. This difference in valley width for the two ends is due, probably, in a great measure, to preglacial conditions. It is more than likely, that the preglacial divide was located near the south end of the valley, with its western end farther down stream, and therefore wider. The west end of the valley is fully three fourths of a mile wide, with inclosing walls rising 1000 feet and more above the bottom, sloping at a steep angle—less than 45°.

The valley further holds the largest lakes distributed along any one of the valley bottoms (see Fig. 2). Careful soundings were made of all the lakes located in this valley, and two showed their bottoms to be considerably below sea level. The position in the lakes where soundings were taken are marked on Fig. 2. After the sounding data were obtained, several possibilities naturally suggested themselves to account for this condition, in the lakes. A close examination of all the conditions, however, resulted in the elimination of all save one of the possibilities. Stream erosion with subsequent depression is eliminated on the ground of extreme irregularity of valley bottom. On the north and near the west end of the valley, the attitude of the strata is

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[1] *Ibid.*, Bull. Geol. Soc. Amer. 1897, Vol. VIII, p. 255.

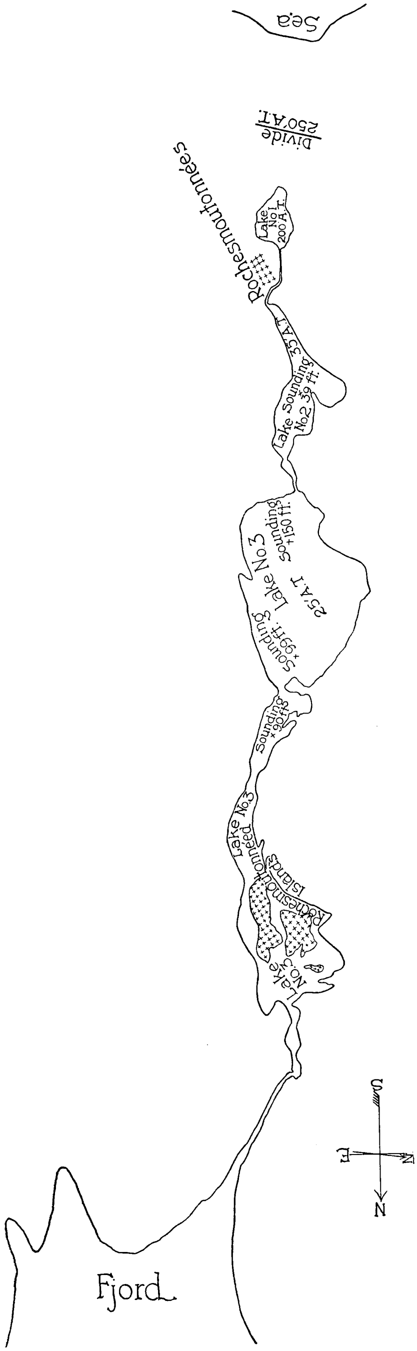

FIG. 2

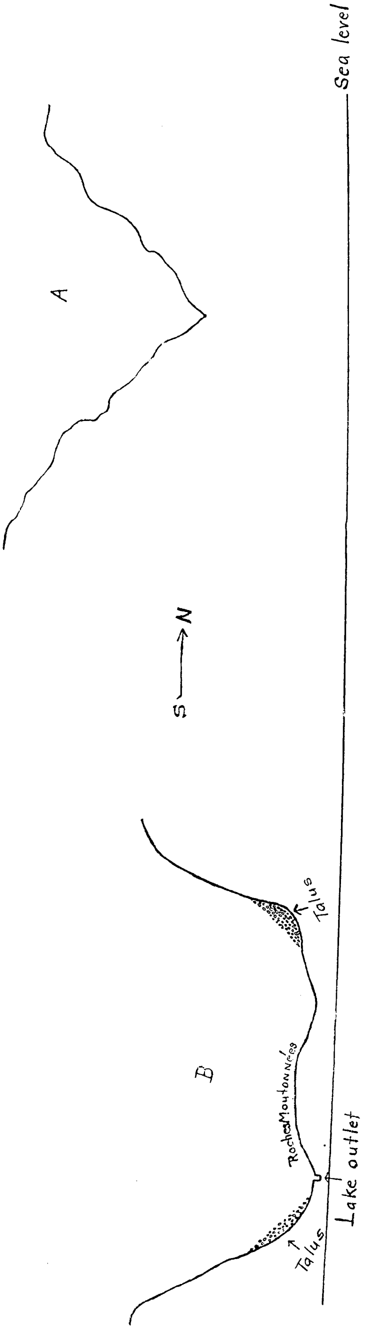

Fig.3. Cross-section of valley 'AB'.
A = E. End.
B = W. End.

that of an overturned fold, whose axis is at right angles to that of the valley. The position of the strata proved that at no point could the valley owe its origin to folding. Rock structure and position were also opposed to origin by differential weathering. The tracing of the same and equivalent strata on the two sides of the valley would preclude faulting. Damming by deposition of morainic material is untenable, since no moraines of any extent occupy any portion of the valley.

The only other possibility to account for these lakes is that of "*ice erosion.*" A brief description of the lakes in this series, with the closely associated glacial phenomena, will best show the evidence for their glacial origin.

The first lake is the only one of this series with bottom above sea level. It is located 60 feet below the valley divide and 165 feet above the surface of the middle lake. It is more or less saucer-shaped in outline, and is, with the exception of the east side, entirely inclosed between highly polished and striated moutonnée forms.

The middle lake, marked lake No. 2 of Fig. 2, lies immediately against the high, precipitous south wall of the valley, and inclosed entirely by moutonnée forms on its north, south, and west sides. It is entirely surrounded by rock in place with its bottom 39 feet below sea level. The moutonnée forms on the north side of the valley are highly polished and planed, with glacial grooves and striae greatly intensified, reaching from the lake's surface up to an elevation of 100 feet. These are coincident with the trend of the valley.

The space between the middle lake and lake No. 3 of Fig. 3, is occupied by moutonnée forms of well-rounded outline and slight elevation. Lake No. 2 drains into lake No. 3 through a rock channel some 50 yards across and about 100 yards long, carved between the close-lying moutonnée hills.

The lake occupying the west end of the valley lies, for most of its length, immediately against the high, precipitous north side. It is something over a mile in length, very narrow, and quite irregular in outline, closely resembling a stream. It is

15 feet above sea level, and in its deepest part—near its head—is 150 feet below sea level. Perfectly developed glacial grooves and striae, with direction coincident with the axis of the valley, extend for quite a distance along the south border of the lake. The outlet channel is cut into solid rock, and averages from four to five feet in depth, with a U-shaped cross-section. The overflow passes over a low point in the divide between the lake and fjord on the southwest side of the valley. The divide is highly glaciated, and stands 25 to 50 feet above the lake level. As can be seen from Fig. 3, the portion of lake near the outlet is dotted with moutonnées rising to a slight elevation above the waters and forming a group of small islands in the lake. Bowlders of varying dimensions are found poised in various positions over the tops of nearly all the largest roches moutonnées in this valley. It will be further observed that the valley axis, AB of map, is approximately coincident with a westward advance in the general glacial movement over the peninsula. Further, that the largest and deepest water bodies are located in the northwestern portion of the peninsula, which portion is shown in a subsequent part of this paper to have been subjected to a period of more or less intense local glaciation. On the high hilltops forming the southwestern limits of the valley are found remnants of once larger local glaciers.

As a class, the valley lakes observed on the peninsula, range in size from something over a mile in length down to the smallest size basin. In outline, some were saucer-shaped—width and length about equal—but generally the length greatly exceeded the width, and when so found were invariably characterized by irregularity of outline. They varied from a few feet to 150 in depth, and in all cases their circumferences were marked by rock in place, proving them to be true *rock-basin* lakes. With but few exceptions they are prevailingly shallow and filled, more or less around their edges, with rock fragments derived from the valley sides, due to shattering by frost. Approximately eight to ten feet above summer water level and along the edges of parts of a few of the larger lakes were noted slender but perfectly formed beaches. These may represent storm levels, or they may be the result of climatic changes. While the valleys probably cannot in all cases be ascribed to the same cause, the lakes associated with the valleys are, apparently, the result of differential ice erosion, and are true rock-basins, since they are walled in by rock *in situ* on all sides.

Dust wells and pools on the ice-surface.—The marginal surface area of the glacier ice was found dotted with numerous circular holes, varying from a quarter of an inch to several feet in diameter, and averaging probably several feet in depth. These were filled nearly to their tops with water, and their bottoms were invariably covered with a thick layer of dust. Professor Barton[1] has described the same condition to the south of this locality in the Umanak district, where he states, that the pits are confined to a marginal zone of about one mile in width, beyond which, and towards the interior, the ice surface becomes comparatively smooth. Professor Chamberlin[2] has observed the same conditions farther north along the west coast, and has fully discussed their origin in a previous number of this JOURNAL.

Other larger pools were seen. Professor Tarr[3] noted an especially large one, occupying a depression in the ice, of about one quarter of a mile in length in the direction of its longest axis, very shallow in depth, and revealing clear smooth ice, with no sediment over its bottom. No observation was made concerning its outlet, and Professor Tarr states that the pool probably represents a case of differential meeting.

Lakes due to other causes.— Along the ice margin, lakes were found, in places, formed by the usual ice marginal processes. A majority of these marginal lakes are due to a walling in of the numerous depressions of the extremely irregular surface of the peninsula, by the more or less steep ice-front on one side, and the slopes of the depressions of the land on the other. Each of these was fed by a marginal stream flowing along the ice front, which was, in turn, made up from the numerous smaller streams flowing off of the ice at its front. In some instances the lakes had been recently drained revealing heavy and conspicuous silt deposits, which necessarily were irregular in position, as is characteristic of marginal lakes. Some were found draining through tunnel outlets in and under the ice.

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[1] Op cit., p. 216.

[2] JOUR. GEOL., Glacial Studies—Greenland, IV, Vol. III, 1895, p. 215.

[3] Communicated by letter to the writer.

Morainal formed lakes, both by means of the masses ponding back the waters, and as kettles occupying the depressions in the morainal accumulations, were not uncommon.

Lakes noted at other points.—Rock inclosed bodies of water similar to those on the upper Nugsuak were noted at the following points: Turnavik Island, off the middle coast of Labrador; Big Savage Island, Hudson Strait; Icy Cove, the extreme southern coast of Meta Incognita; Niantilik, Cumberland Sound; and at several places along the Greenland coast to the south of the Upper Nugsuak peninsula. So far as observation extended their origin and development have been essentially the same.

At Niantilik a large number of typical rock-basins, resembling in every respect the Nugsuak lakes, were observed. Where studied, these were found developed in true strike valleys, and in case of the larger ones, roches moutonnées islands of slight elevation and formed by the hard layers of steeply tilted gniess were found. The character of these lakes left no doubt as to their being true rock-basins formed in part by ice erosion. Their entire circumferences were in many cases encircled by rock in place.

THE VALLEYS

No grouping of the valleys according to direction could be effected, since they were found trending with all points of the compass. An apparent series of major valleys were observed, cutting the peninsula in a direction varying from an almost east and west course to one at nearly right angles to this, which invariably had a seaward termination.

In a very general way, the larger valleys are best described as being very deep and broad, somewhat U-shaped in outline.

There are wide variations, however, from the steep sided and precipitous profile to that of considerably gentler slope. Frost action has wrought widespread results on the original glacial outlines of this form, resulting generally in a modification tending toward a less precipitous outline.

It has already been stated that numerous dikes of a basic eruptive rock, probably diabase, are found cutting the gneiss in an approximately vertical attitude. The basic dike rock of the peninsula has yielded more readily to the attack of the atmospheric agencies than the inclosing gneiss. Subsequent ice advance removed most of the residual decay, resulting in some instances, in the ice eroding considerably below the line of actual decay, determining thereby one set of the major valleys. The U-shaped outline is especially applicable to this type of valley.

Similar conditions apparently prevailed at Turnavik, Labrador, as on the Nugsuak. The rock is a coarse porphyritic gneiss cut by dikes of a basic eruptive, many of which have been eroded to a depth of some 20 to 25 feet by the ice, and in some of which residual decay was still to be seen, indicating a greater preglacial decay of the dike than country rock.

In the Umanak district of North Greenland, Professor Barton,[1] observed that the dikes of eruptive rock had not been eroded below the level of the inclosing gneiss, but instead, they were found, in some instances, standing "out in relief above the gneiss."

No petrographic study has been made of the rocks in the localities mentioned above, hence it would not be safe to say whether the difference could be accounted for on lithologic grounds, or whether it is due to a difference in glacial conditions.

A second type of valley, but of minor importance, on account of slight development, was noted, the origin of which was traceable to the etching out of the softer rock layers in the highly tilted strata by differential atmospheric weathering, and can therefore be classed as strike valleys.

Subsequent to the period of widespread general glaciation, the northern ends of the valleys have undergone considerable modification from a period of local glaciation, which is now confined to the northern side of the peninsula, and in its last declining stage Owing to the work of local glaciation, more or less contrast is observed in the topography of the opposite ends of the approximate northwest-southeast trending valleys (see Fig. 3). Glacial filling, principally bowlders with some till; abundance of typically developed roches moutonnées, glacial grooves, striae, planing and polishing, conspicuously characterize all of the major valleys.

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[1] BARTON, GEO. H., Technology Quarterly, 1897, 10, 236, 237.

A large number of the major valleys were associated with dikes of basic rock. So far as studies were extended, the mass of fact pointed to the conclusion, that this type of valley was due to differential preglacial decay with subsequent ice erosion. The entire set of major valleys, everywhere viewed on the peninsula, are distinctly preglacial; and while their origin was not apparent in every case, they have all suffered considerable subsequent modification from ice erosion.

A parallel is probably found in Canada, where Dr. Robt. Bell[1] has observed greenstone dikes protruded into granites. The dikes have subsequently been worn out and at present form valleys occupied by lakes and streams.

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[1] BELL, DR. ROBT., Bull. Geol. Soc. Amer. 1894, V, 364.